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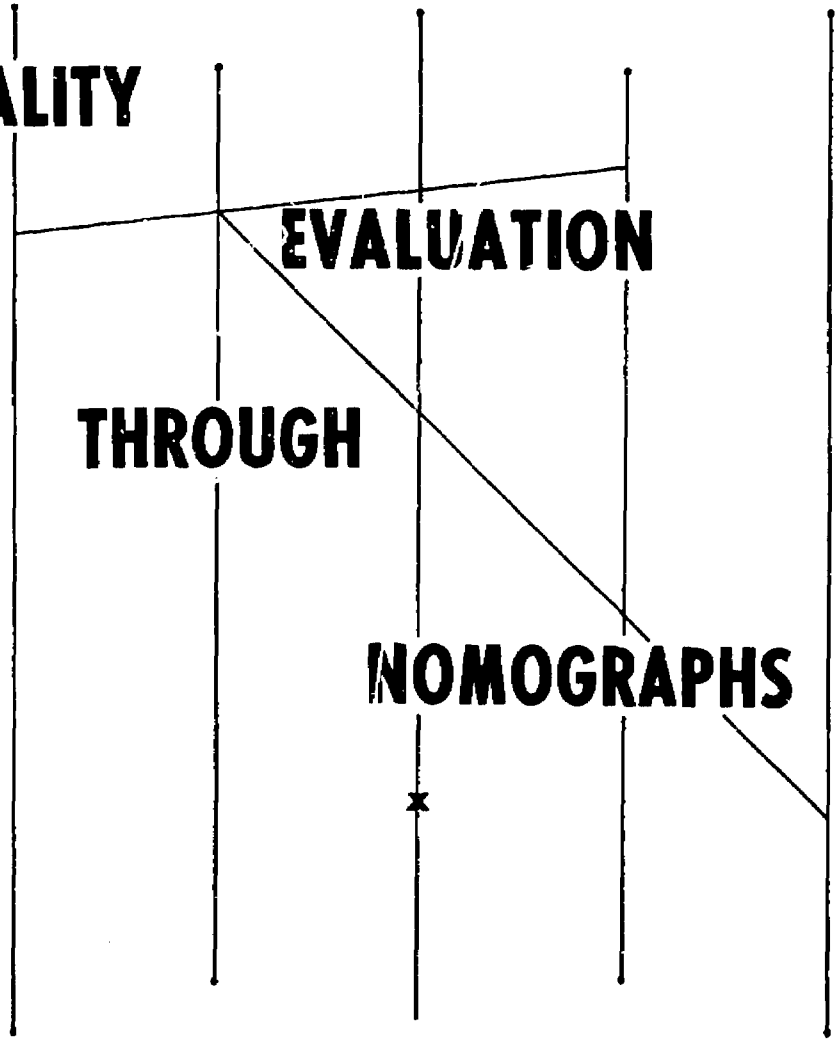
ABSTRACT

The Quality Measurement Project of New York State, in an attempt to simplify the assessment of school effectiveness, has applied nomographic techniques to this process. Essentially a nomograph is an easy graphic method of obtaining a predicted score without the use of the original regression equation upon which it is based. In the case herein described, the average reading score (grades 5 and 9), average arithmetic score (grade 5), and average composite score (grade 5) on the Iowa Tests of Basic Skills, Form 4 may be predicted from average IQ, average mother's education, and instructional costs. Likewise average arithmetic score (grade 8) may be predicted from mother's education, father's education, and IQ and average composite score (grade 8) from father's education, IQ, and instructional costs. The computation of each of these variables for use on the included nomographic charts is described. The process of entering these figures on the charts and obtaining the predicted score (a matter of drawing two or three lines) is explained. Once the predicted score has been obtained, it may be compared with the actual average score and school effectiveness may be assessed by use of the standard error. This process is also described. For a description of the study and the statewide norm tables upon which the nomographs are based see TM 000 316. (DG)

QUALITY EVALUATION THROUGH NOMOGRAPHS



THE UNIVERSITY OF THE STATE OF NEW YORK
THE STATE EDUCATION DEPARTMENT
BUREAU OF SCHOOL PROGRAMS EVALUATION
ALBANY, NEW YORK

ERRATA SHEET

Page	iv	Regression Analysis p. 2
"	v	Figure 1 - Thermometer
"	5	Table 1 - last line, 3d column - should read IQ
"	18	1st paragraph, line 6 - circumstance
"	27	#10 - should read (underscore title) Design of Liquid, Solid and Hybrid Rockets

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The University of the State of New York
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Albany, New York 12224
April 1970

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FOREWORD

The Quality Measurement Project has had as one of its purposes the devising of tools which the school administrator can use to gauge the effectiveness of his organization. Such an objective necessitates a search for methods of presenting meaningful information about many facets of educational programs. Expressing complex interrelationships in simple and easily understood terms is an ever present problem. Applying nomographic techniques to determine school system effectiveness is one solution to this problem.

Charles Armstrong, a retired staff member of the Quality Measurement Project, conceived of the application of nomographic techniques as a means of determining school system effectiveness. Gerald Wohlferd, Associate in Education Research, authored this document. Lee Wolfe, Chief of the Bureau of Statistical Services, helped design the nomographic charts.

This document is offered as an illustration of the use of nomographic techniques in assessing school system effectiveness.

LORNE H. WOOLLATT
Associate Commissioner for
Research and Evaluation

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QUALITY EVALUATION THROUGH NOMOGRAPHS

Introduction

How good is a particular school system? Answering this question has traditionally been the responsibility of boards of education. The superintendent of schools or chief school administrative officer has had to evaluate student progress for the board of education. In the evaluation of his system the administrator has relied upon both subjective and objective measures. Subjective measures have consisted of such things as observations of pupils and teachers at work, teacher comments, and feedback from parents and pupils. Objective measures have often been based upon achievement test results, comparison of cost figures, or percent of pupils graduating. Both subjective and objective measures, more often than not, have failed to include relationships with each other or with other factors. That relationships must be considered has been demonstrated by the Quality Measurement Project of the New York State Education Department.[4,5,12,13]

Such relationships have in the past been presented by the QMP in the form of figures and tables in the School Quality Workbook.[14] A new method of assessing the quality of a school system, that of nomographs, is illustrated herein. Nomographs are unique in that while quality determination is accomplished in a relatively simple manner, relationships are clearly visible in graphic form.

As nomographs are based upon mathematically derived regression equations, a short explanation of regression analysis is offered for the neophyte statistician. An explanation of the structure and use of nomographs follows.

Regression Analysis

Regression analysis offers a mathematical technique of simultaneously interrelating many quantified measures. Application of regression techniques results in a mathematical formula which assigns weights, or strengths, to the various measures in relation to each other in the prediction of a specific measure. Auxiliary figures indicate the accuracy and degree of prediction.

Regression analysis results can be used in at least two ways in education. First, a formula can be derived which provides weights, or relative strength indicators for the variables used. Thus, if one were to predict an achievement score in reading by using intelligence, parental education, and school expenditure measures, the resultant regression equation would indicate the power of each of the three predicting measures to each other.

A second use of regression analysis is to compare an actual value with a predicted value. Substitution of data of an individual school district into a general derived equation results in a predicted score which can then be compared with the actual score for the district. By this method one may determine if children of the district are achieving better than expected, as expected, or below expected levels.

Nomographs

An extension of regression analysis is the construction of nomographic charts. Nomographs express in chart or graphical form the relationships expressed as mathematical symbols in the regression equation. They combine several graphic scales on a single sheet of paper so that reference can be made from one to the other. The value of nomographs lies in the simplicity and speed by which information from one

scale may be translated into information on another scale. For example, the formula $\frac{9}{5}C + 32 = F$ may be used to convert Fahrenheit temperature levels to centrigrade readings or vice versa. Each time one wished mathematically to convert from one scale to the other it would be necessary to enter a known reading into one side of the formula and to the calculate the corresponding reading of the other. Water boils at sea level at 100° centrigrade. If one did not already know the boiling point on the Fahrenheit scale, the number 100 would need to be entered into the above formula in place of C to yield 212° as the equivalent Fahrenheit value. The derivation of other equivalent values would demand mathematical recalculation for each new situation.

The relationship between the two temperature scales, expressed mathematically above, can also be expressed in a simple nomograph. Reference to figure 1, which is such a nomograph, reveals how quickly and easily values from the centigrade scale can be translated into Fahrenheit values, and vice versa. Equivalent values are directly opposite each other on this nomograph. For example, the boiling point of the centrigrade scale of 100° is directly opposite and parallel to 212° on the Fahrenheit scale. The freezing point of water is 32° on the Fahrenheit scale. Its corresponding value on the centigrade scale is directly opposite and is easily found to be 0°. The above illustrations of the ease and speed of determining relationships is an indication of the facility by which more complex relationships can be expressed through the use of nomographs.

The concept of presenting relationships in nomographic form is not new,[3] but has been used and is being widely used in engineering.[1,2,6,10] Use in the field of education,[11] however, has been limited.

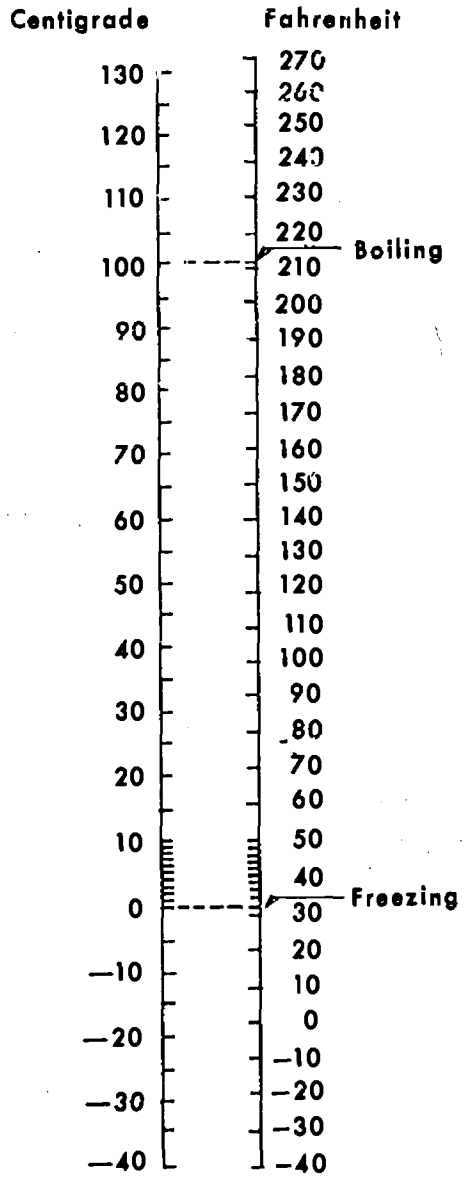


Figure 1. Relationship of centigrade and Fahrenheit thermometer scales.

Regression analysis was one of the statistical techniques utilized by the Quality Measurement Project (QMP).[5,13] The construction of nomographs based upon the Quality Measurement Project regression analyses is a logical step in providing educators with management tools. Accordingly, six nomographs (three each for grades 5 and 8) were constructed. In each of the nomographs a school system average score on a test of achievement is the predicted measure. Average scores were secured through administration of the Iowa Tests of Basic Skills, Form 4.[8] Grade equivalent averages were used. Other data necessary to complete the nomographs are mother's education level, father's education level, IQ, and average instructional costs. Directions for compilation of the above factors in preparation for entry into the nomographs are to be found in appendixes A through D.

Content of the Nomographs

No nomograph is a duplicate of any other (see appendix E). The scales on each are often unique to that nomograph even though there is a general similarity among them. Data incorporated in the columns or scales of the six nomographs are distilled in table 1 below.

Table 1

Subject Matter Contained in Nomographs

Grade	Nomograph Number	Nomograph Subject	Subject of Line or Column (from left) 1	2	3	4	5
5	1	Reading	IQ	Line	Reading	Instruct. Costs	Mother's Educ.
	2	Arithmetic	IQ	Line	Arithmetic	Mother's Educ.	Instruct. Costs
	3	Composite	IQ	Line	Composite	Instruct. Costs	Mother's Educ.
8	4	Reading	IQ	Line	Mother's Educ.	Reading	Instruct. Costs
	5	Arithmetic	Mother's Educ.	Line	Father's Educ.	Arithmetic	IQ
	6	Composite	Father's Educ.	Line	I	Composite	Instruct. Costs

The achievement scales upon which the predicted score will be determined are found as the third column from the left margin on 5th grade nomographs. The corresponding basic skill scales on 8th grade nomographs are the fourth column from the left margin. An unscaled column, the use of which will be explained later, appears as column two in all nomographs.

Instructions for Use of Nomographs. Directions for securing and preparing the information dealing with characteristics of the school system are to be found in appendixes A-D. As each piece of information is derived, it can be entered on the proper scale or scales by an 'X' to represent its location. Lines are then drawn in a designated sequence to join the marked locations on the various scales until the predicted achievement average score is found where the last line intersects the achievement scale. Use of colored pencils to record X's and lines aids in distinguishing entries from the basic nomograph content.

The sequence of connecting scales by lines varies with the grade. Each of the columns on the nomographs has been numbered from the left across the top of each page. The unscaled vertical line has also been numbered. Sequences of connections are shown in table 2.

Table 2

Column Connection Sequence

Grade	Sequence	
	First Connection	Second Connection
5	Column 1 to Column 4	Column 2 to Column 5
8	Column 1 to Column 3	Column 2 to Column 5

The procedure to follow is illustrated below for 5th grade reading score of a hypothetical school system. The school district may have found the various measures of their district to be as follows:

Average IQ (5th Grade)	= 110.5
Average Instructional Costs Per Pupil	= $553.2
Average Mother's Education (5th Grade)	= 3.9
Average Reading Achievement (5th Grade)	= 5.94

Since the achievement area cited above is 5th grade reading, nomograph number 1 will be used in the illustration.

The position of each of the measures is first located on its corresponding scale (see figure 2) and noted by an 'X'. Scale 1 is then joined with scale 4 by a straight line between the X's (see figure 3). Next, scale 5 is joined to scale 2 by a straight line. This line originates on scale 2, where scale 2 and the line joining scales 1 and 4 intersect (see figure 4). The predicted achievement score is to be found where the last drawn line (between scales 2 and 5) crosses scale 3. In the illustrative case the predicted average reading score is approximately 5.59, while the actual measured score is 5.94. Thus, the illustrative school system is averaging +.35 months above its predicted score.

At the bottom of each sheet containing a nomograph may be found: the mathematical formula upon which the nomograph was based, the standard error of the predicted measurement, the school year in which the majority of the measures were secured, and the number of school districts (N) whose data were included in the derivation of the mathematical formula. Of particular interest to the user of the accompanying nomo-

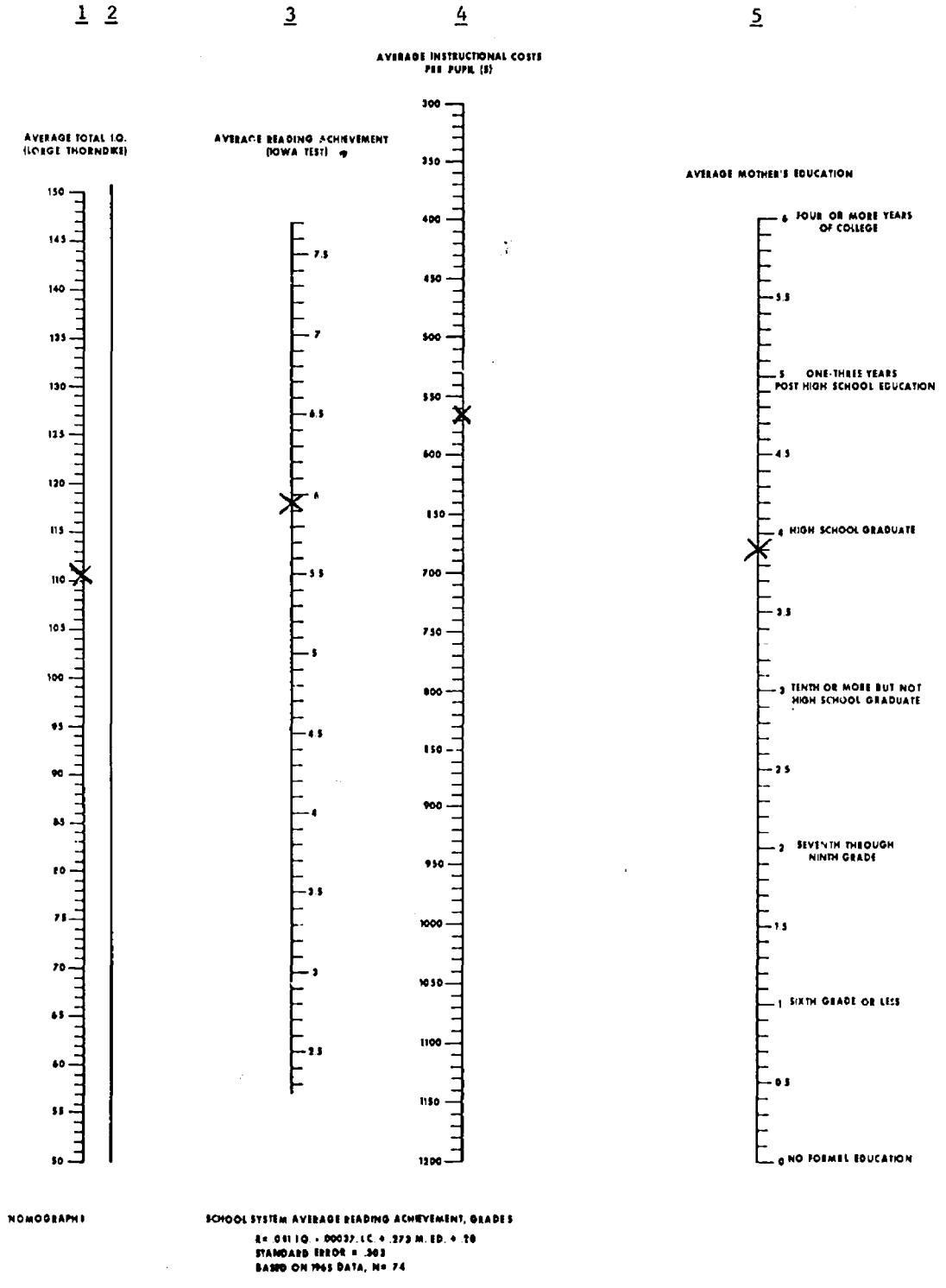


Figure 2. Illustration of entry of values on scales.

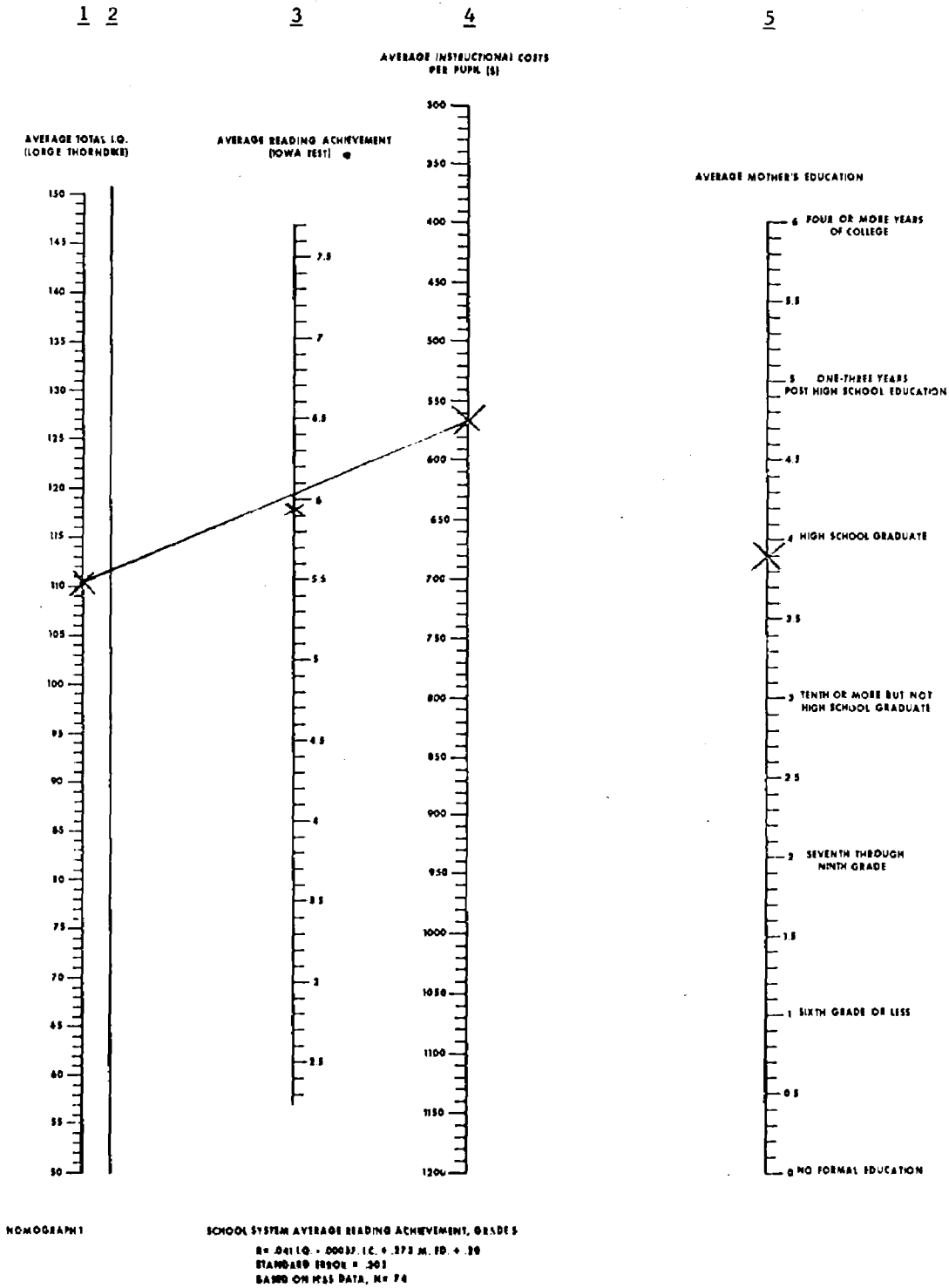


Figure 3. Illustration of joining of two measures by line.

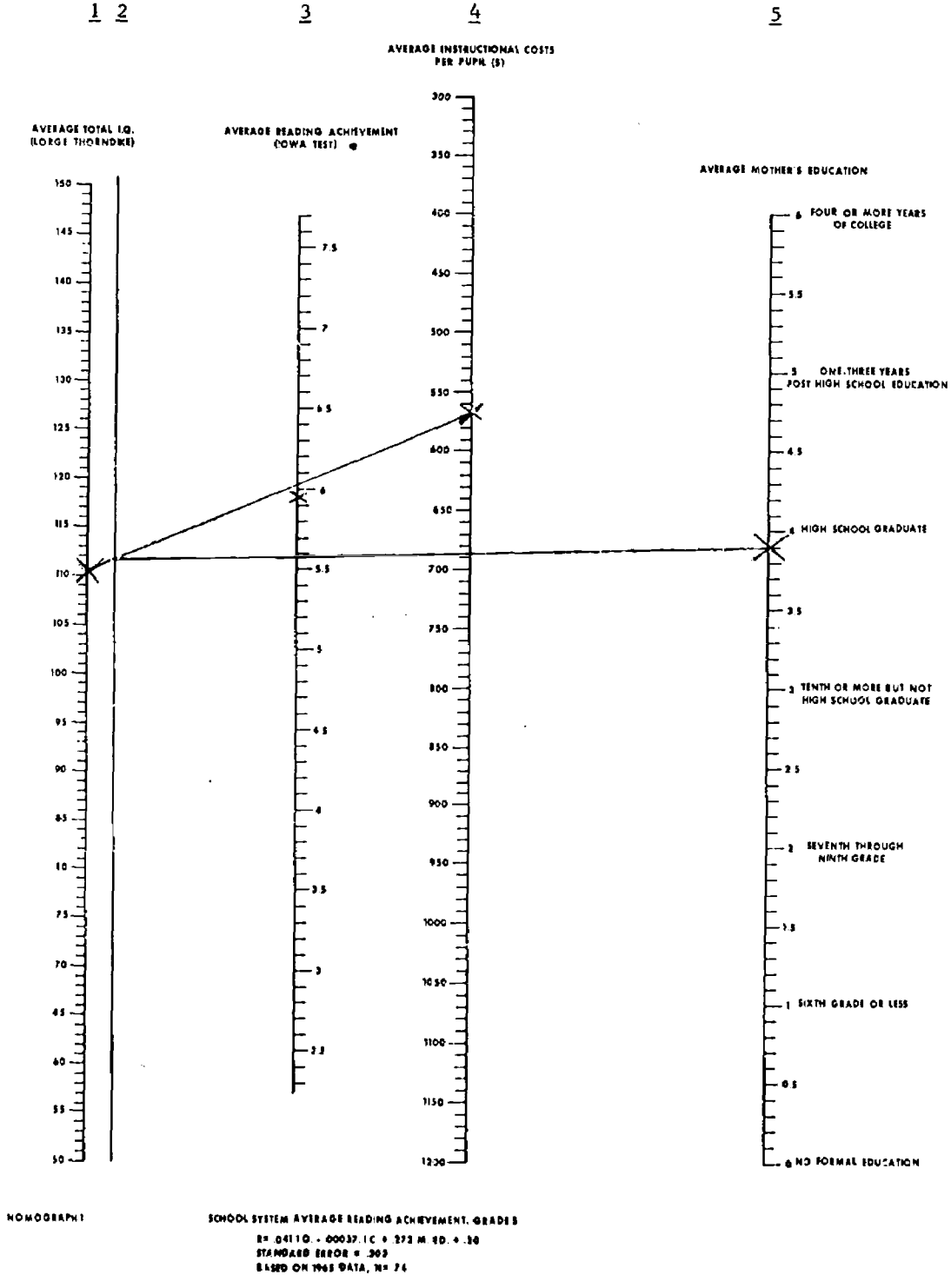


Figure 4. Illustration of completion of nomograph.

graphs (appendix E), is the standard error. The predicted score is only as accurate as the measures used in the prediction. The standard error describes the accuracy of the predicted score. In the illustration the standard error is .303. The actual reading score is about 3½ months above the predicted score. The difference between the actual and predicted scores (.35) is greater than the standard error of measurement (.303). Therefore, the conclusion would be drawn that the difference is probably a real difference. A difference of an actual score from a predicted score which is smaller than the standard error, suggests the actual score must be considered as equivalent to the predicted score. The above statements regarding the relationships of differences and standard errors hold true for either plus or minus differences.

Though the above statements are statistically defensible, a word of caution is advisable. Since the systems included in the sample may not be representative of New York State schools--New York City was not included--the data on which the regression equations (and subsequently the nomographs) were based may be biased. Too, not all elements of education which effect achievement in the basic skills have been included in the equation; as additional important elements are identified and their relationships to achievement are determined, accuracy of prediction can be increased. Finally, only three achievement measures

(reading, arithmetic, and composite) are included in this document. Additional achievement areas should be included to make assessment of school effectiveness more nearly complete. Logically, other objectives of education should also be included in any evaluation of school system effectiveness. The nomographs described in this report may serve as one approach to assess certain limited areas of a school's total program.

APPENDIXES

Appendix A

Derivation of School System Average
Achievement Scores

The scores used in developing the nomographs were obtained from the school districts which participated in the Quality Measurement Project testing program in the fall of 1965. Each system administered the Iowa Tests of Basic Skills, Form 4,[8] to its 5th and 8th grade pupils. Children in special class, such as those for the mentally retarded, were omitted. Student grade equivalent scores for each subject area were averaged by grade for each district. The district averages were used to develop the equations used to calculate the predicted scores whose scales appear as part of the nomographs.

School districts wishing to use the nomographs should use the same commercial test. The use of scores obtained by administering any other achievement battery is not a valid procedure because of the lack of congruence among batteries. As the nomographic scales are based upon fall testing, the battery should, if possible, be administered in the fall. If testing is done at any other time of year, the averages obtained should be converted to fall equivalents. This is accomplished through use of the percentile tables, which appear at the rear of the "Manual for Administrators, Supervisors, and Counselors."[8] The average grade equivalent score should be converted to a percentile, using the table appropriate for the time of year testing takes place; then the percentile should be located in the 'beginning-of-year' norm table where its grade equivalent score may be secured.

Grade equivalent average scores are expressed in the nomographs as decimal fractions with the whole number representing years and the decimal as part of the year. Thus, an average grade equivalent score of 57.4 which a system might obtain from averaging the grade equivalent scores of their 5th grade students' would, in the nomograph, be expressed as 5.74. This would indicate that the average achievement of the students of the system was 5 years and about 7 months.

Appendix B

Directions for Securing Average
Mother's and Father's Education Level

Information about the extent of formal education of each child's parents may be secured from the cumulative records, from parent questionnaires, or from other sources of data. Large city districts may wish to sample their students or parents. Smaller districts may find it necessary to include several grades, while very small districts will need to include the parents of all students.

After the educational level has been determined for each parent, a value is assigned. Both mother's education and father's education are quantified through use of the following scale.

6 = 4 or more years of college

5 = 1 - 3 years posthigh school education

4 = High school graduate

3 = 10th grade or more but not high school graduate

2 = 7th through 9th grade

1 = 6th grade or less

0 = No formal education

After numbers are assigned for each parent an average is obtained by totaling separately for each sex the assigned scale values and then dividing by the number of parents of that sex. The resulting average educational level is the figure entered on the corresponding parental scale of the nomographs.

Average mother's education is contained on five of the six nomographs, not appearing on monograph 6. Average father's education is contained only on nomographs 5 and 6.

Appendix C

Directions for Securing Average IQ Level

The instrument used to secure pupil IQ was the Lorge-Thorndike Intelligence Tests.[9] The total IQ figure was used in construction of the nomographs. Use of nonverbal or verbal IQ in the place of total IQ is a questionable procedure. Total IQ scores from a grade 4 testing may be used if 5th grade scores are unavailable. Similarly, 7th grade IQ scores may be used under similar cirsumstances in place of grade 8 scores.

Sampling may be utilized for large systems. Pupil scores for each grade are averaged as in appendix A. The IQ average score for the grade is then entered into the nomograph. IQ appears on all six nomographs. The average IQ score derived for grade 5 is entered on nomographs 1 through 3. Grade 8 average IQ is entered on nomographs 4 through 6.

Appendix D

Directions for Obtaining Average
Instructional Costs Per Pupil

The instructional costs which were used in the regression analyses and which formed the basis for the scale used in the nomographs were drawn from the data of the 1964-65 school year, the year preceding that in which achievement testing took place.

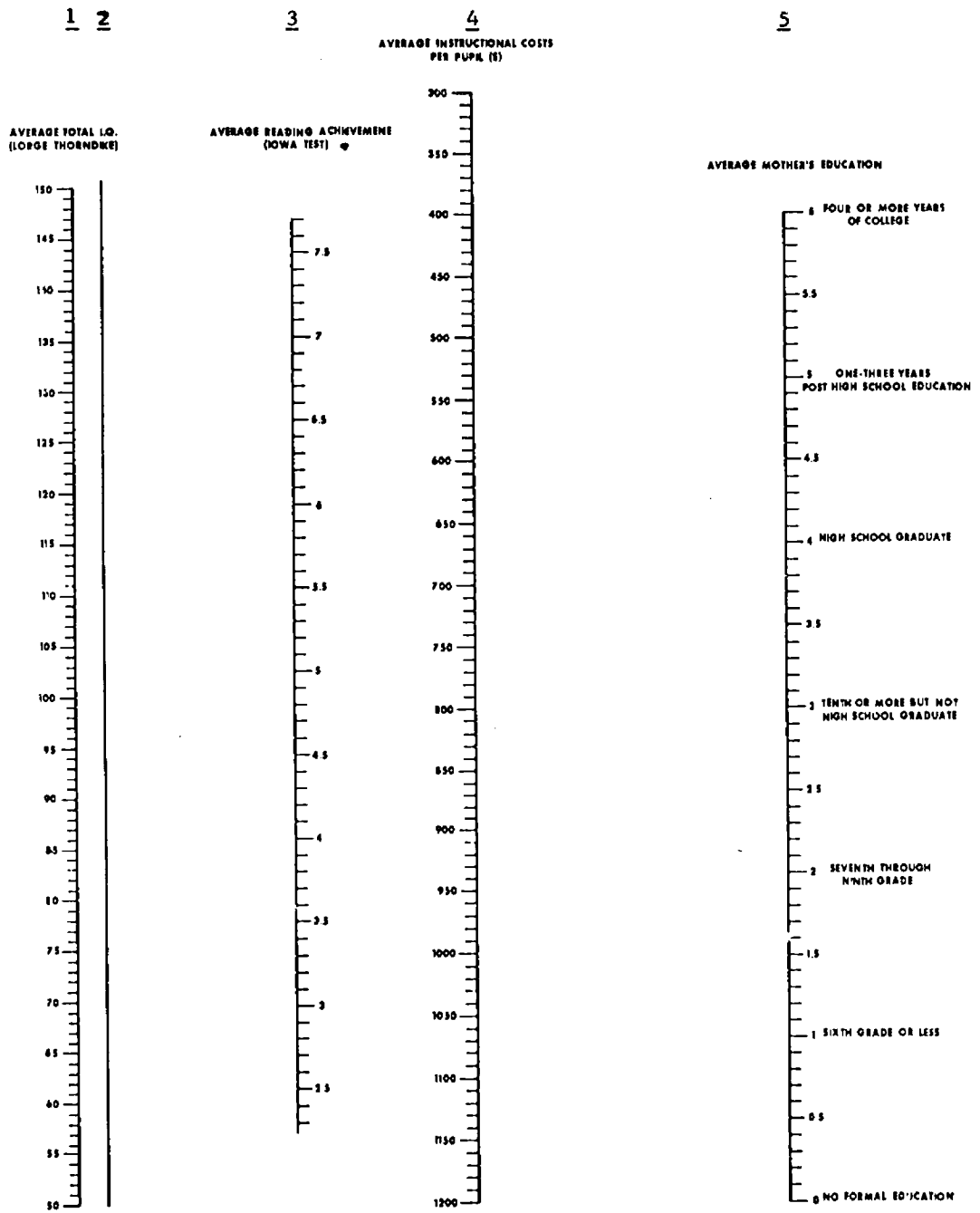
The size of the school system is balanced with its cost by expressing costs on a per pupil basis. The school system gross instructional cost figure is account number 296-999 in the Uniform System of Accounts for School Districts[7] and is entitled, "Instruction--Regular Day." This figure is then divided by the "Weighted Average Daily Attendance" (WADA). WADA is derived as follows: The average of the best four attendance periods is used as the attendance figure, with kindergarten pupils counted as ½, pupils in grades 1-6 counted as 1, and grade 7-12 children counting as 1¼. Gross instructional cost is divided by WADA to obtain the "Average Instructional Costs Per Pupil" which is used in all but one of the accompanying nomographs. The same figure is entered on all of the five nomographs.

Appendix E

Nomograph Charts and Condensed Directions

Directions for completion of nomographs.

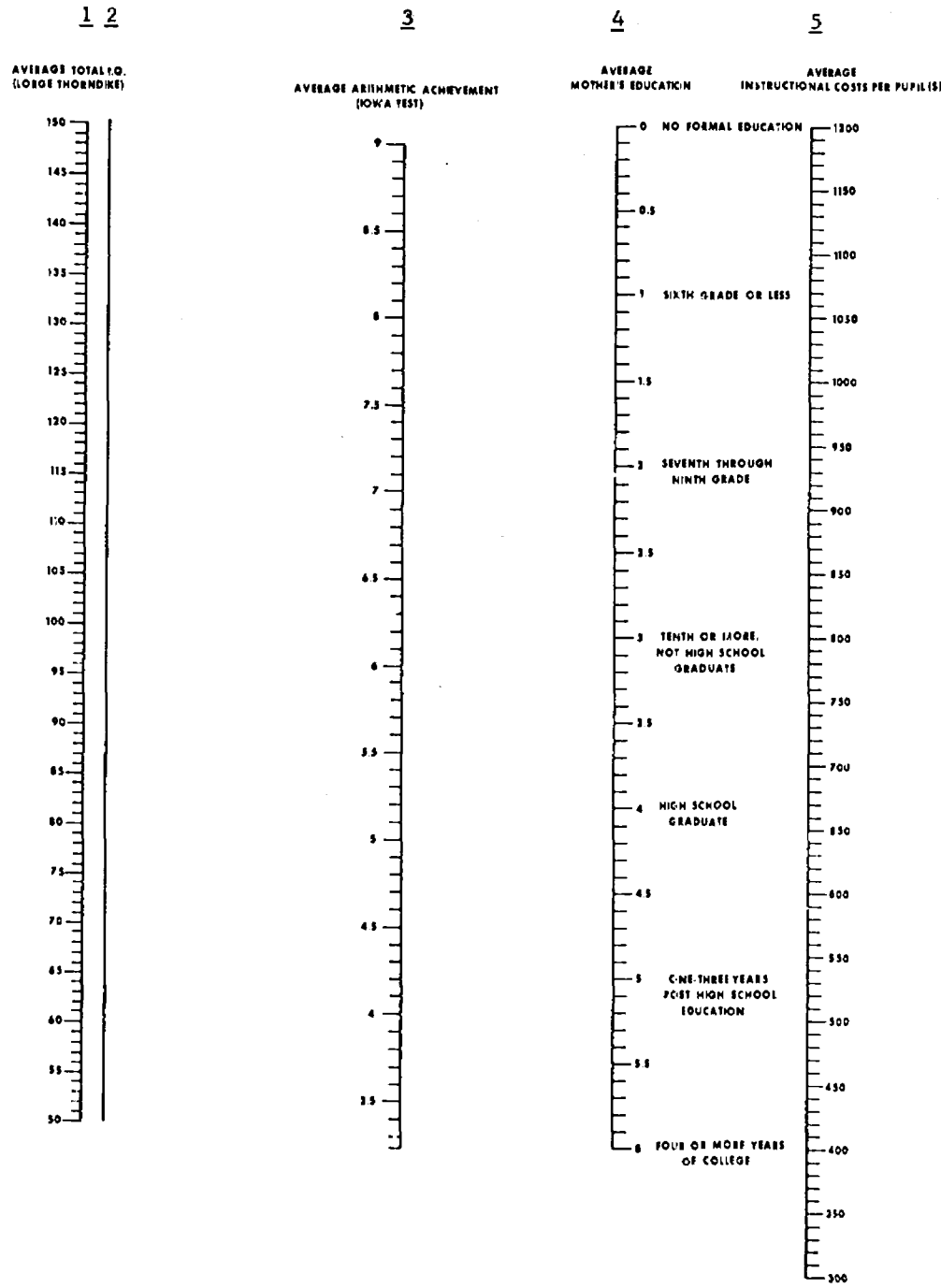
1. Locate positions of measures on each scale with 'X'.
2. Draw line connecting positions in order shown in Table 2.
3. Determine predicted score as place where last drawn line crosses basic skill achievement column.
4. Calculate differences of actual scores from predicted scores.
5. Determine if differences are greater than standard errors.



NOMOGRAPH 1

SCHOOL SYSTEM AVERAGE READING ACHIEVEMENT, GRADE 5

R = .041 I.Q. + .00037 I.C. + .373 M. ED. + .36
STANDARD ERROR = .303
BASED ON 1963 DATA, N = 74



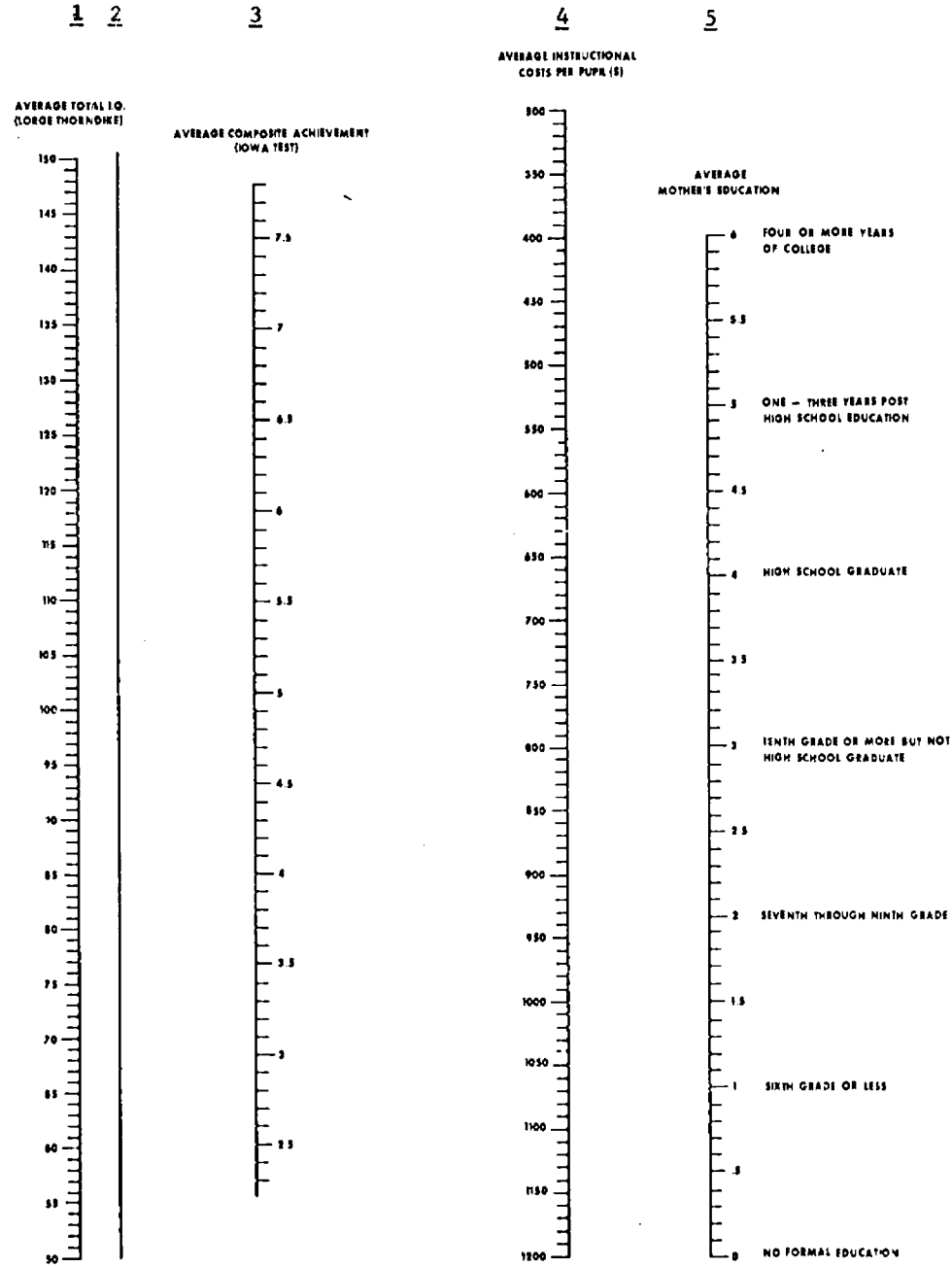
NOMOGRAPH 2

SCHOOL SYSTEM AVERAGE ARITHMETIC ACHIEVEMENT, GRADE 5

A= .033 I. Q. - .038 M. Ed. + .0031 I. C. + .57

STANDARD ERROR = .334

BASED ON 1963 DATA, N= 74



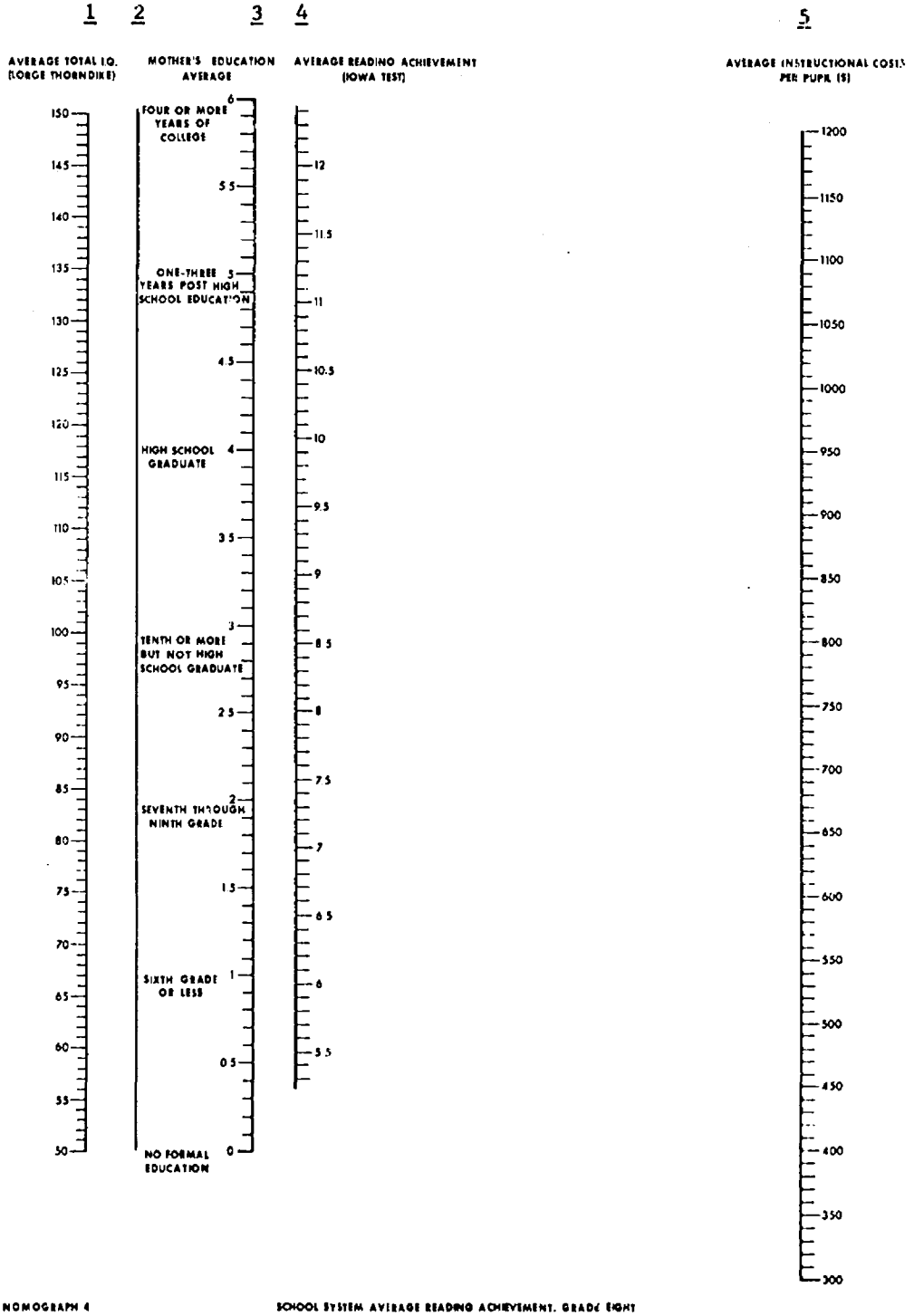
NOMOGRAPH 3

SCHOOL SYSTEM, AVERAGE COMPOSITE SCORE, GRADE FIVE

C= .043 I.Q. - .00045 I. C. + .216 M. Ed. + 33

STANDARD ERROR = .342

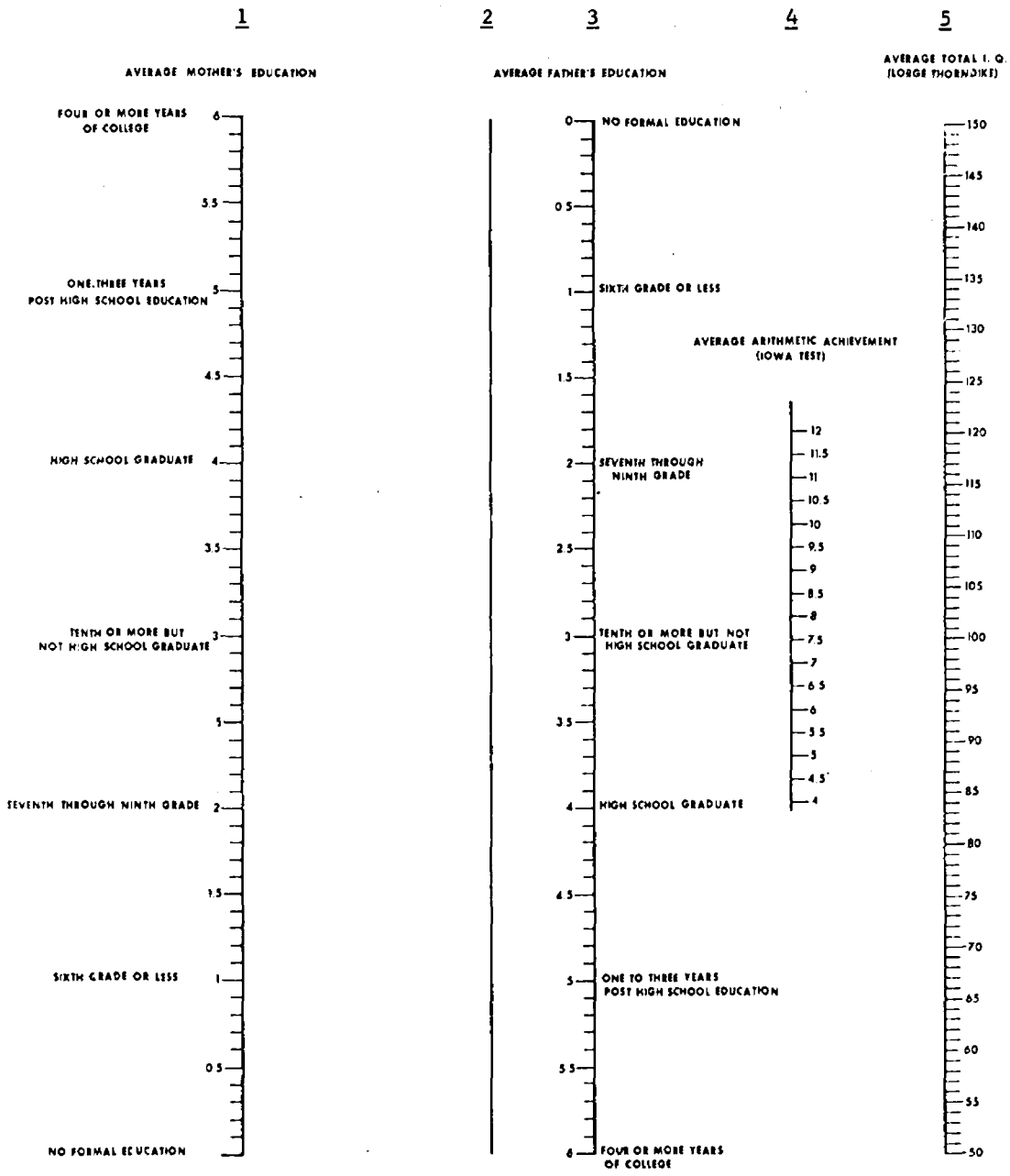
BASED ON 1965 DATA, N = 74



NOMOGRAPH 4

SCHOOL SYSTEM AVERAGE READING ACHIEVEMENT, GRADE EIGHT

R= .0407 I.Q. + .299 M. ED + .00237 I.C. + 1.8
STANDARD ERROR= .355
BASED ON 1965 DATA, N= 71



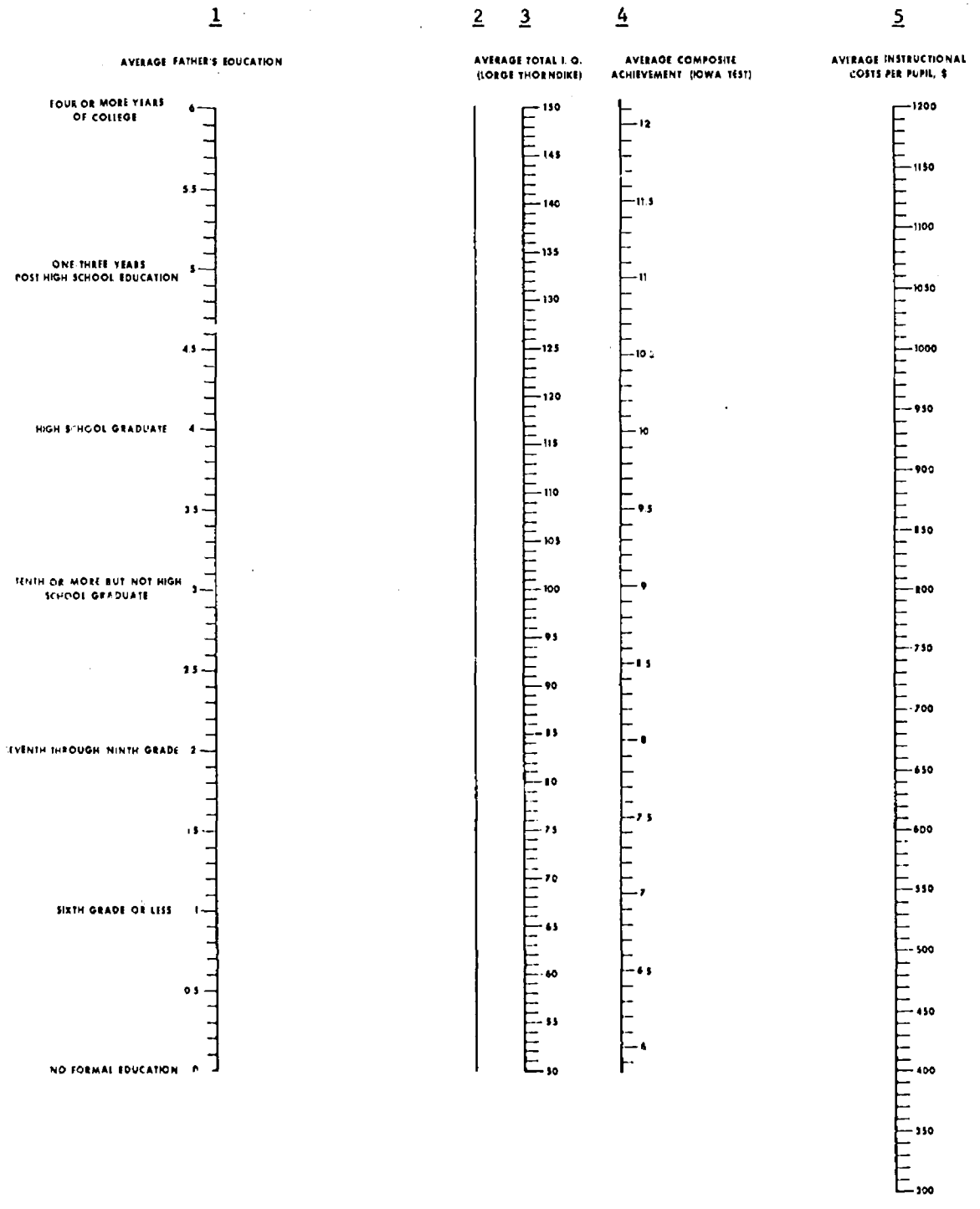
NOMOGRAPH 5

SCHOOL SYSTEM AVERAGE ARITHMETIC ACHIEVEMENT, GRADE EIGHT

A= .377 M. Ed. + .904 F. Ed. + .149 I.Q. -3.79

STANDARD ERROR= .36

BASED ON 1965 DATA, N= 91



NOMOGRAPH 6

SCHOOL SYSTEM AVERAGE COMPOSITE ACHIEVEMENT, GRADE EIGHT

C= 108 F. ED. + 0346 I.Q. + 00268 L.C. + 3. 079
STANDARD ERROR= 371
BASED ON 1965 DATA, N=71

Bibliography

1. Applebaum, Max H., Electronic Engineering Nomographs, G/L Tab Books, Blue Ridge Summit, Pa., 1968.

2. Davis, Dale S., Chemical Engineering Nomographs, McGraw-Hill Book Co., New York, 1944.

3. D'Ocagne, M., Traité de Nomographic, 2nd ed., Ganthie-Villars, Paris, 1908.

4. Firman, W.D., et al, Procedures in School Quality Evaluation, New York State Education Department, Albany, Jan. 1961.

5. Goodman, S.M., The Assessment of School Quality, New York State Education Department, Albany, March 1959.

6. Hoelscher, Randolph P., Graphic Aids in Engineering Computation. McGraw-Hill, New York, 1952.

7. Levitt, Arthur, Uniform System of Accounts for School Districts, Department of Audit and Control, Albany, 1965.

8. Lindquist, E.F. and Hieronymus, A.N., Iowa Tests of Basic Skills, Form 4, Houghton Mifflin Company, Boston, 1964.

9. Lorge, Irving, et al, Lorge-Thorndike Intelligence Tests, Houghton Mifflin Company, New York, 1964.

10. Peters, Robert L., Design of Liquid, Solid and Hybrid Rockets, Hayden Book Co., New York, 1965.

11. Wolfe, Lee R., "Determinant and Geometric Methods for Nomographing Regression Equations," paper presented at AERA, February, 1969.

12. Wohlferd, G.H., "Factors Which Affect School Quality," Journal of Secondary Education, Sampler Issue, New York State Association of Secondary School Administrators, Albany, May 1962, pp. 16-17.

13. ---, et al, "Scholastic Achievement and Relevant Factors," ARGR Journal, University of Delaware, Vol. 9, Nos. 1 & 2. November-April 1968.

14. ---, et al, School Quality Workbook, New York State Education Department, Albany, January 1963.